FIELD ADAPTATION
OF TELEMETRY INSTRUMENTATION
IN SURFACE OILSANDS MINES

FINAL REPORT

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FINAL REPORT

TO

CANMET
MINING RESEARCH LABORATORIES,
WESTERN OFFICE
ENERGY, MINES AND RESOURCES
CALGARY, ALBERTA

BY

ECOLOGICAL AND RESOURCES CONSULTANTS LIMITED

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PREFACE

This is the final report for Contract No. 0SQ85-00116, covering field adaptation of telemetry instrumentation in surface oil sands mines, submitted to CANMET, Mining Research Laboratories, Western Office, Department of Energy, Mines and Resources, Calgary, Alberta.

The responsibilities for this project were shared among three consultants of Ecological and Resources Consultants Ltd., in Fredericton, N.B., each dealing primarily with the aspects most suited for his technical experience.

Other technical and general support was provided as needed.

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ABSTRACT

Two ground stability problems are of concern at Syncrude's oilsands mining operation in northern Alberta: the stability of high walls in the area of the dragline operation, and the stability of the tailings dyke. The geotechnical group at Syncrude has been searching for a reliable and continuous monitoring system which could replace or supplement their present survey system based on manually operated borehole inclinometers. The Canada Centre for Mineral and Energy Technology (CANMET) suggested a test, in the area, of a radio telemetry monitoring system which had been developed by the Ecological and Resources Consultants Ltd. and successfully employed with electronic tiltmeters in a mining subsidence study in southern British Columbia.

The telemetry system consists of a computer controlled master station which can interrogate, at any preprogrammed time intervals, up to 256 remote stations (slave units). Each slave collects and transmits survey data from four monitoring sensors. The main question in adapting the telemetry system to Syncrude's monitoring requirements was whether the system could work (transmit the data) over distances up to 6 km with partially obstructed lines of sight in the environment of Syncrude's operation with possible interference from multiple high power cables, intensive radio communications at various frequency bands, etc.

In August 1985, the telemetry system, with five slave stations, was installed and tested on both sites: on a dragline bench, and on the tailings dyke. No major problems were encountered in the tests. At the time of writing this report, the telemetry system is still being tested by Syncrude's geotechnical group with generally favourable results. The tests indicate that the telemetry system has a great potential to improve the monitoring system at Syncrude. Several small modifications to the present telemetry system have been suggested in order to increase its capability, increase to six the number of sensors for each slave, and increase the operational temperature limit from the present -25°C to -40°C.

ACKNOWLEDGEMENTS

The consultants wish to acknowledge with thanks the efforts of the following persons whose contributions were invaluable to the success of this project:

- Dr. M.Y. Fisekci, the Scientific Authority, who was extremely supportive throughout the project;
- Dr. N. Stewart, of CANMET, who helped in the laboratory and field adaptation of the telemetry system;
- members of the Geotechnical Engineering group of Syncrude Canada Ltd., especially Messrs. Allan Fair, the supervisor, Steve Tan and Terry Stevens, who have conducted extensive field tests with the system; and finally,
- research assistants at the University of New Brunswick, particularly Messrs. J. Secord and P. Romero, who assisted in the calibration of tiltmeters and in the design of tiltmeter adaptors.

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1. INTRODUCTION

A prototype radio-telemetry system for monitoring ground movements in mining areas was developed by the Ecological and Resources Consultants Ltd. (ERCL) (referred to as the Consultants in this report) at the request of CANMET in 1980 and expanded with some modifications in 1983. Three years of field tests in an area of underground coal mining near Sparwood, B.C., proved that the system was reliable and able to operate in adverse weather conditions without recharging its batteries for one year when using tiltmeters as sensors of the ground movements. A full description of the telemetry/tiltmeters system has been given in two reports, submitted in 1980 and 1983, by the Consultants to CANMET in Calgary.

In April, 1985, Dr. M.Y. Fisekci of CANMET contacted the Consultants about the possibility of adapting the prototype telemetry system to monitor ground movement in an oil sands surface mining operation (Figures 1 and 2) of Syncrude Canada Ltd. in northern Alberta. On 22 May, 1985, the Consultants received a formal request from Supply and Services Canada to submit a proposal for an adaptation of the telemetry instrumentation in surface oil sands mines.

Two ground stability problems have been identified as warranting priority attention in oil sands mining. One of these is the need for more assurance of the security of the dragline working bench. Shallow (20 m) block slides (Figure 3) occur along thin clay bands located near the top of the oil bearing formation; the crest of the highwall including the bench from which the dragline would operate may slide into the excavation [Fair and Lord, 1984]. Since total mine production comes from four draglines, the loss of one of these multi-million dollar machines (Figure 4) would have obviously serious consequences to the plant. Hence, elaborate precautions are taken to locate and monitor the status of potential zones of weakness in the working bench. A critical element in the existing monitoring program is the measurement of shear displacement in boreholes located along the line of advance of the production dragline (Figure 5).

Manually operated (Figure 6) borehole inclinometers have been the main tool of the monitoring surveys [Fair and Lord, 1984] on the dragline benches. The method, though reliable, is labour intensive, expensive, and it does not provide continuous and real-time information on the behaviour of the highwalls. For several years, the geotechnical group at Synchrude has been trying to develop a more economical and continuous monitoring system [Fair and Isaac, 1985].

Security of the tailings dyke is another problem. The tailings dyke is some 20 km long, of which about half is located on a foundation of till underlain by marine clay. Lateral movement of the dyke (outward from the basin) occurs in the clay bed. Long-term measurement of this movement may serve as an indicator of dyke stability and as a basis for specifying the safe height for the tailings dyke. Here, as well, the geotechnical engineers have been looking for a suitable monitoring system.

On 30 May 1985, Dr. Fisekci and Dr. Chrzanowski of ERCL visited the mining site to discuss the monitoring needs at the dragline operations and at the tailings dyke. Dr. A.F. Fair, supervisor of the Syncrude geotechnical group, and other members of the group, expressed an interest in testing the telemetry system as a potential tool for replacing or supplementing the manual inclinometer surveys at the dragline operations and as a possible main system for the dyke monitoring.

On 14 June 1985, the Consultants submitted to CANMET the requested proposal for the adaptation and testing of the prototype telemetry/tilmeter system, and on 19 July 1985, the contract agreement, entitled "Field adaptation of telemetry instrumentation in surface oil sands mines" was signed.

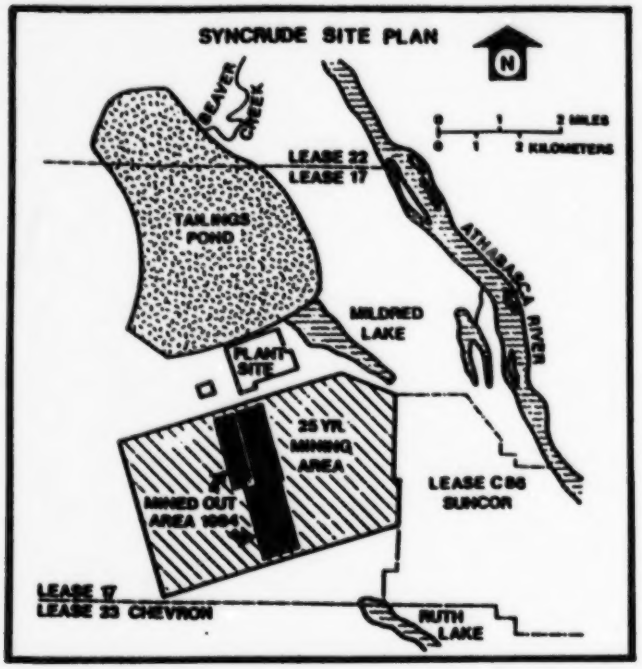


FIG.1. Syncrude Mine Site (after Fair and Lord,1984)

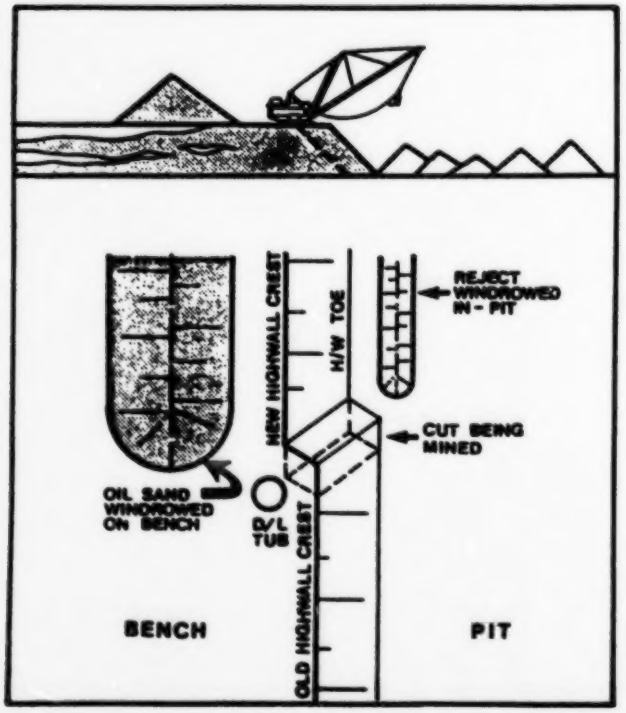


FIG.2. Syncrude Dragline Mining Method
(after Fair and Lord,1984)

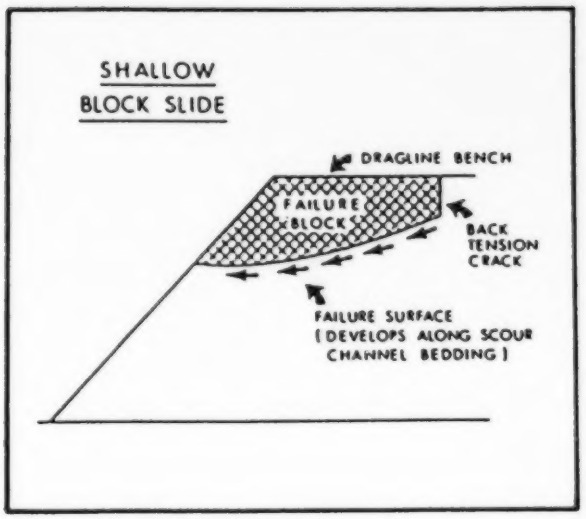


FIG.3. Typical Shallow Block Slide
(after Fair and Lord,1984)

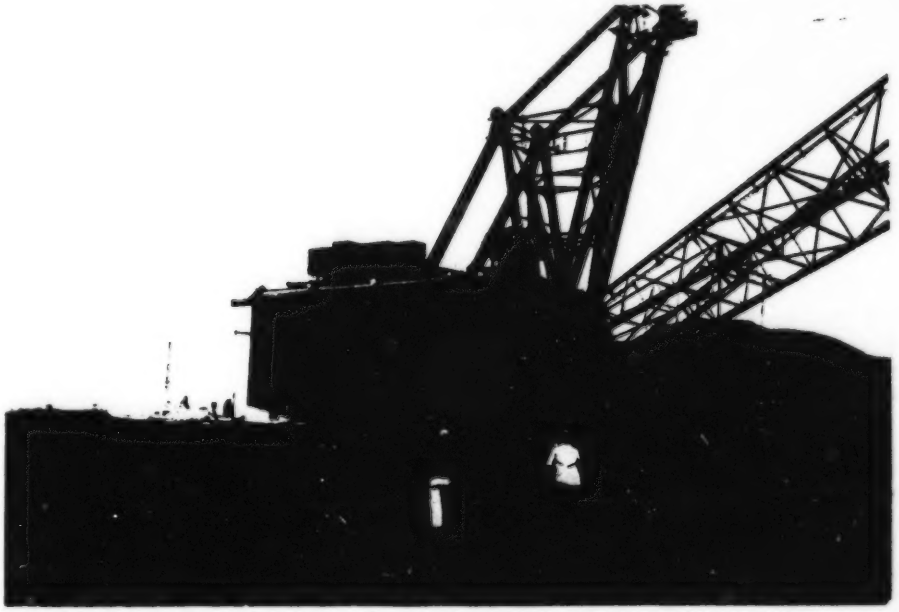


FIG.4. One of the Draglines

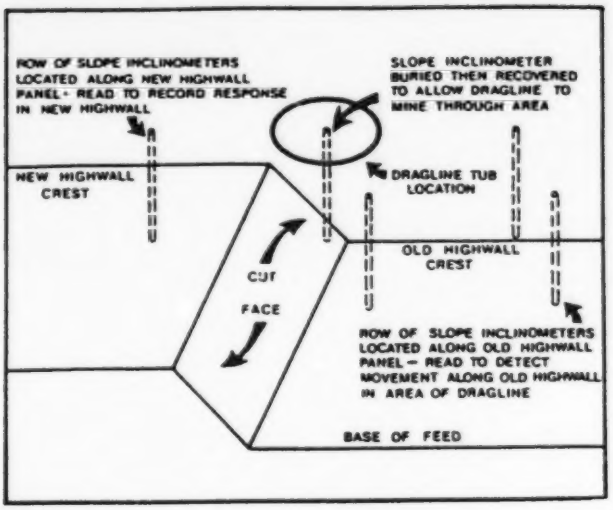

ROW OF SLOPE INCLINOMETERS LOCATED ALONG NEW HIGHWALL PANEL - READ TO RECORD RESPONSE IN NEW HIGHWALL
SLOPE INCLINOMETER BURIED THEN RECOVERED TO ALLOW DRAGLINE TO MINE THROUGH AREA
NEW HIGHWALL CREST
DRAGLINE TUB LOCATION
OLD HIGHWALL CREST
CUT FACE
ROW OF SLOPE INCLINOMETERS LOCATED ALONG OLD HIGHWALL PANEL - READ TO DETECT MOVEMENT ALONG OLD HIGHWALL IN AREA OF DRAGLINE
BASE OF FEED

FIG.5. Typical layout of Borehole Inclinometers in the Area of Dragline Operation (after Fair and Lord,1984)

FIG.6. Manual Profiling of Borehole with Inclinometer

2. STATEMENT OF WORK

The main question in adapting the prototype telemetry system to the monitoring surveys in the oil sands mine was whether the system could work at all over ranges of up to 6 km in the active mining environment containing high voltage power lines, a variety of mining equipment, and multiple radio communication signals. The other question to be answered was how long the battery operated system could survive without recharging the batteries in the severe climate conditions with almost continuous transmission of the survey data.

In order to answer the questions, the experiments were planned according to the Statement of Work of the contract agreement:

1. A short-term trial in the vicinity of the production dragline to demonstrate that the radio-telemetry system will function in the mining area.
2. A longer-term trial at the tailings dyke to demonstrate the reliability and the transmission range of the system.

The Statement of Work specified the following activities to be carried out:

1. Examine the sites and prepare a proposal to test the telemetry/tiltmeter system for monitoring the highwall and tailings embankment, including a work schedule and final cost.
2. Modify instrumentation, and prepare cables and ancilliary equipment as required for the two trials.
3. Install tiltmeters on existing anchors, commission the system, and train local engineers.
4. Provide trouble shooting and maintenance advice for a period of two months.
5. Prepare a report on the performance of the system and the validity of the data obtained.

The telemetry system, with all necessary modifications, had to be ready for the tests before the end of August, 1985, so that the installation and preliminary testing could be made in reasonable weather conditions of late summer and early fall 1985. The cost of the adaptation and testing had to be kept within $20,000.

3. THE TELEMETRY SYSTEM

The telemetry system is essentially a computer network with a microprocessor-controlled central station (master) and remote stations (slaves). Communication between the master and up to 256 slaves takes place over a radio link.

The portable slaves are battery operated with a battery lifetime dependent upon the interrogation rate. Each slave in the present system is powered by one 12 V, 55 Ah and two 12 V, 6 Ah lead-acid, gell-cell type batteries. Figure 7 gives the battery lifetime in terms of number of interrogations (K) and number of slaves (N) in the system. For instance, in the case of four slaves being scanned in each interrogation, the batteries should survive ~5200 interrogations, i.e., 185 scans per day (one scan every 10 minutes) for a period of 4 weeks. The diagram was made for an average temperature of +5°C. In -25°C, the number of interrogations will be reduced by about 50%.

The system was designed to work in the temperature range between -25°C to +50°C, and it should survive -40°C with a self-recovery when the temperature again reaches the operating range. It should be mentioned, that the Consultants have had no opportunity to test the present transmitters and receivers (Repco Series 810-040 and Series 810-055) in temperatures below -15°C. Different types of transceivers (Motorola) were used in the aforementioned field tests in Sparwood.

The telemetry system has been designed as a general purpose remote data acquisition system so that any type of sensors producing an electric voltage output, not only tiltmeters, could be hooked-up to the system. In the present system, up to four sensors can be used with each slave station. This could easily be upgraded to six sensors without any major modifications of the system. Use of more than six sensors with one slave would also be possible after some hardware and software changes.

Data acquisition at the slave sites takes place in a reporting-on-demand fashion, with the master interrogating one slave at a time. An introduction of a 'alarm' system at the slaves is also possible, as shall be discussed in section 6.

The master controls the entire operation of the telemetry system. It is based on a commercial microcomputer (IBM-PC). The software support provides for fully automated measurement over long periods of time, as well as for operator intervention. All acquired data can be saved on diskette and printed on a hard copy printer. After a power failure, the system starts up automatically without loss of past data. A remote control facility permits operation of the telemetry system by telephone from any location.

The present system, which has been made available for the Syncrude test, consists of one master station, equipped with the IBM-PC computer, and eight slave units, which include five prototype (called *old*) and three updated (called *new*) units, numbered *old* slaves 0, 1, 2, 3, and 4, and *new* slaves 5, 6, and 7.

In the tests at Sparwood, the telemetry system worked with bi-axial tiltmeters as the sensors of ground movements. The tiltmeters, produced by Terra-Technology Inc, in Seattle, U.S.A., are of a servo-accelerometer type. In the present telemetry system, each tiltmeter required one slave unit (two user channels for each bi-axial tiltmeter). As already mentioned, three tiltmeters (bi-axial) could easily be used with each slave unit taking six out of seven available channels.

Within the eight tiltmeters, which have been made available for the Syncrude tests, five

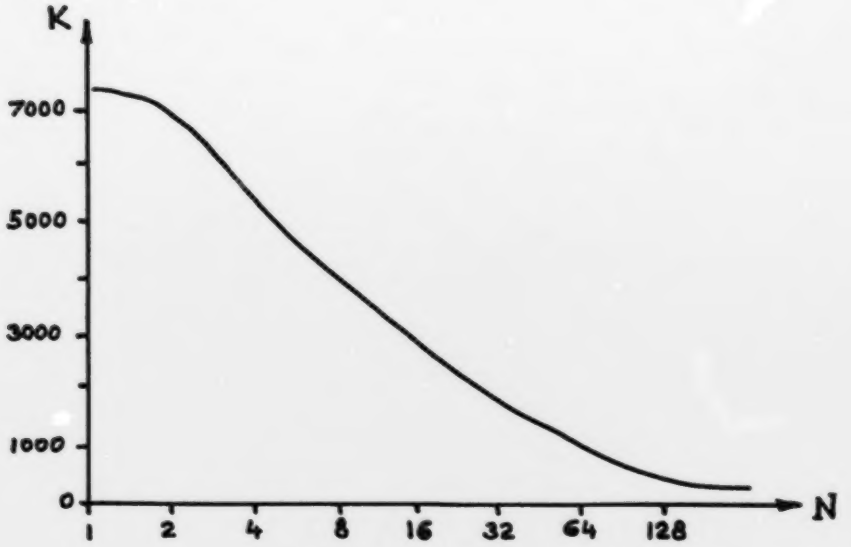


FIG.7. Battery Lifetime in Terms of Number (K) of Interrogations and Number (N) of Slaves at an Average Temperature of + 5°C.

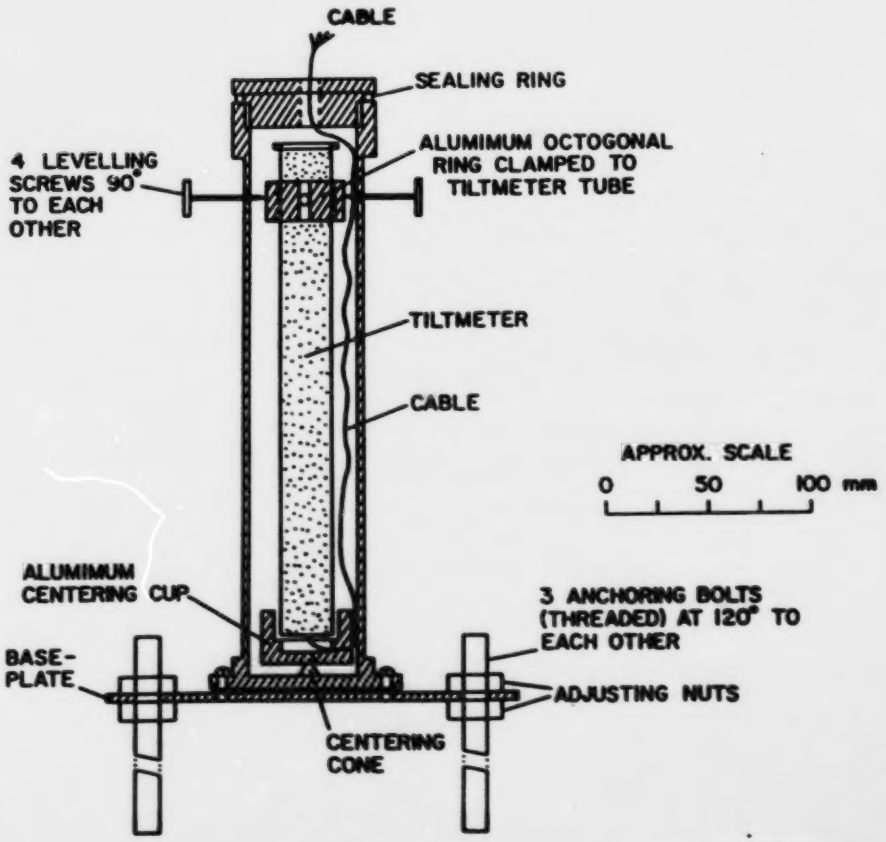


FIG.8. Crossection of the Tiltmeter Housing and Old Anchoring Plate.

tiltmeters have the sensing range of ±6° (upgraded to ±1° through the use of amplifiers in the slave units) and three *new* tiltmeters have the range of ±1°. The 6° tiltmeters are numbered: 101, 103, 104, 105, and 106; and 1° tiltmeters are: 107, 108, and 109. The angular resolution of the tiltmeters is about 2" (seconds of arc). However, the resolution of the telemetry system (7200"/256) is only 28".

The present telemetry system uses the following combination of the slaves and tiltmeters:

Tiltmeter no. 101 with slave no. 1
Tiltmeter no. 103 with slave no. 2
Tiltmeter no. 104 with slave no. 4
Tiltmeter no. 105 with slave no. 0
Tiltmeter no. 106 with slave no. 2
Tiltmeter no. 107 with slave no. 7
Tiltmeter no. 108 with slave no. 6
Tiltmeter no. 109 with slave no. 5.

Any other slave-tiltmeter combination may be used in the field after changing corresponding calibration parameters in the initial computer file.

As was mentioned in the Introduction, a full description of the telemetry system has been given in two ERCL reports which are available from CANMET.

4. ADAPTATION OF THE TELEMETRY SYSTEM AND DESIGN OF THE TEST SURVEYS

Due to the time and financial limitations, the Consultants decided to use the existing telemetry system in the test without any major modifications. Since the main purpose of the proposed tests was to check whether the system could work at all at the Syncrude mining operation, no major effort was made to try to adapt the system at the test stage for an actual gathering of the deformation data and for its interpretation for the production purposes. The tests, if successful from the point of view of the data transmissions, were supposed to give indications what future modifications would be needed in order to use the telemetry system for the actual monitoring surveys of the stability of the highwalls and of the dyke.

The type of sensors to be used in the tests, therefore, was considered of secondary importance because, as already indicated above, practically any type of sensors, whether borehole inclinometers or extensometers or deflectometers, could be adapted to the telemetry system. Therefore, the Consultants decided to use the available bi-axial tiltmeters in the preliminary tests; the same which had been used in the earlier monitoring surveys at Sparwood. Each tiltmeter consists of two servo-accelerometer sensors with their respective A and B axes of tilt sensing being perpendicular to each other. The total dimensions of the encasing cylinder are 25 cm by 2.5 cm. Figure 8 gives a schematic cross section of a specially designed tiltmeter housing and anchoring system which was used in the Sparwood tests. The position of the tiltmeter tube can be adjusted in its verticality by adjusting knobs.

The Consultants, together with the Syncrude geotechnical engineers, agreed that the preliminary field tests on one of the dragline benches would utilize the tiltmeters for monitoring of surface tilts of shallow (3 m deep) boreholes drilled 25 m apart along the route of the progressing dragline. Two tiltmeters were to be placed on top of the casings of two neighbouring boreholes and then moved in a "leap-frog" manner to other boreholes according to the progress of the dragline. This required a design of a new base and anchoring system for the tiltmeters so that they could be quickly and firmly anchored to the top of the borehole casings and easily reset to an approximately vertical position when moved to a new location. Figure 9 shows the design of the new base plate which can easily be set and fastened in a horizontal position by means of the spherical motion and a spirit level. The threaded cone fits into a PVC adaptor which is cemented on the top of the borehole according to the Syncrude design as shown in Figure 2A in Appendix A.

In order to facilitate the transportation of the slave units between the boreholes a carrying platform was designed (Figure 10) on which the two boxes of the *new* slave (battery box and electronic/transceivers box) would fit together. New cable connectors between the tiltmeters and the slave units had to be installed to enable a quick connection of the tiltmeters and to allow for using special extension cables so that the tiltmeters could be installed at a certain distance from the slave units. This was of particular importance in designing the installation of the slaves at the tailings dyke where problems in having the radio intervisibility between the slaves and the master unit were predicted. Figure 11 shows the design of the cable connectors.

Since the telemetry system had not been used for over a year after its tests in Sparwood, it required thorough checking, recalibration, and adjustment. The electronic tiltmeters which generally change their characteristics with time had to be calibrated for the conversion factor K (conversion from mV into seconds of arc), temperature coefficient τ (mV/°C) and drift. The calibration of the tiltmeters was performed in laboratories of the University of New Brunswick in the same manner as given in previous ERCL reports. Table 1 lists the calibration results for all 8

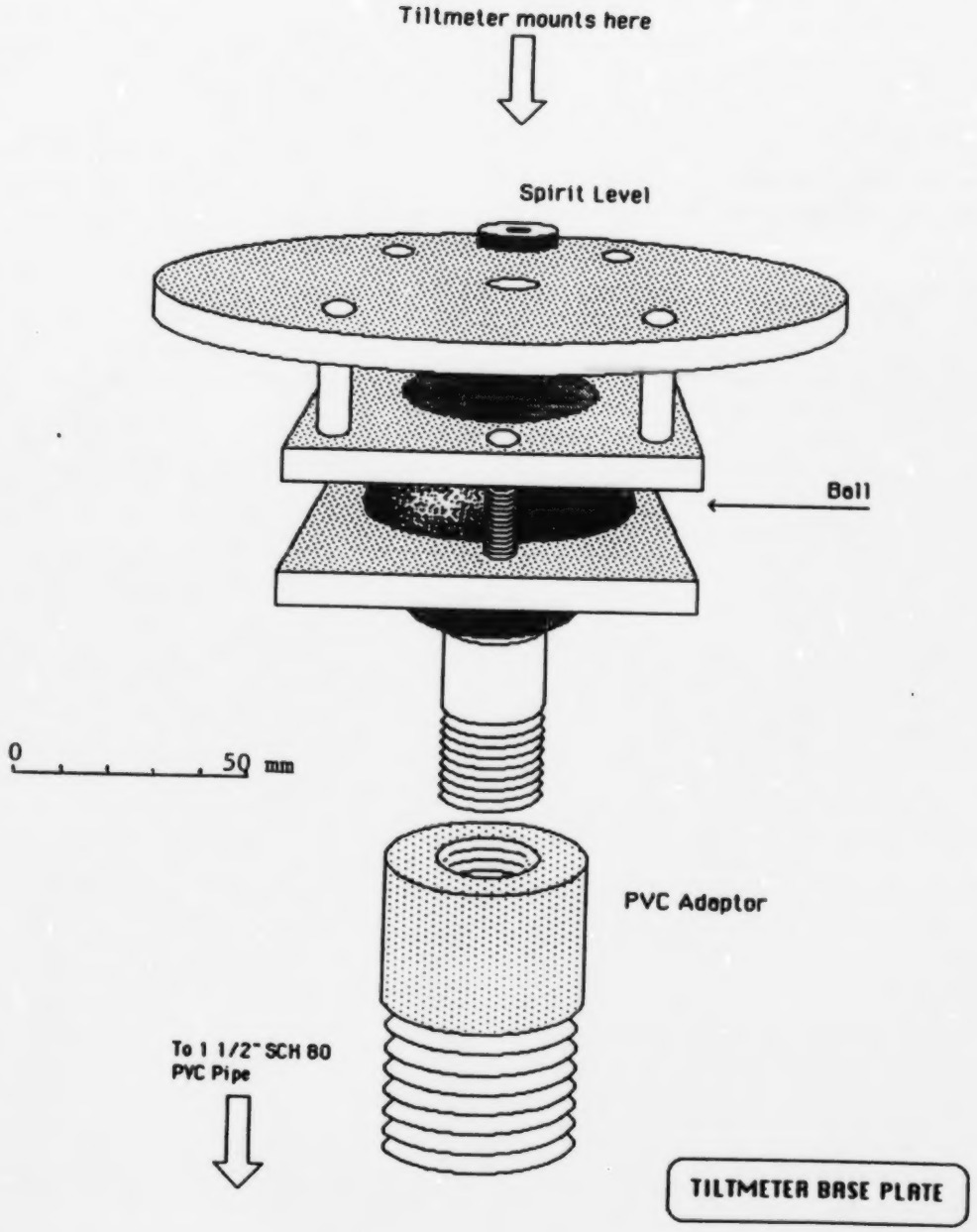


FIG.9. Design of the New Baseplate with the Spherical Setting Device.

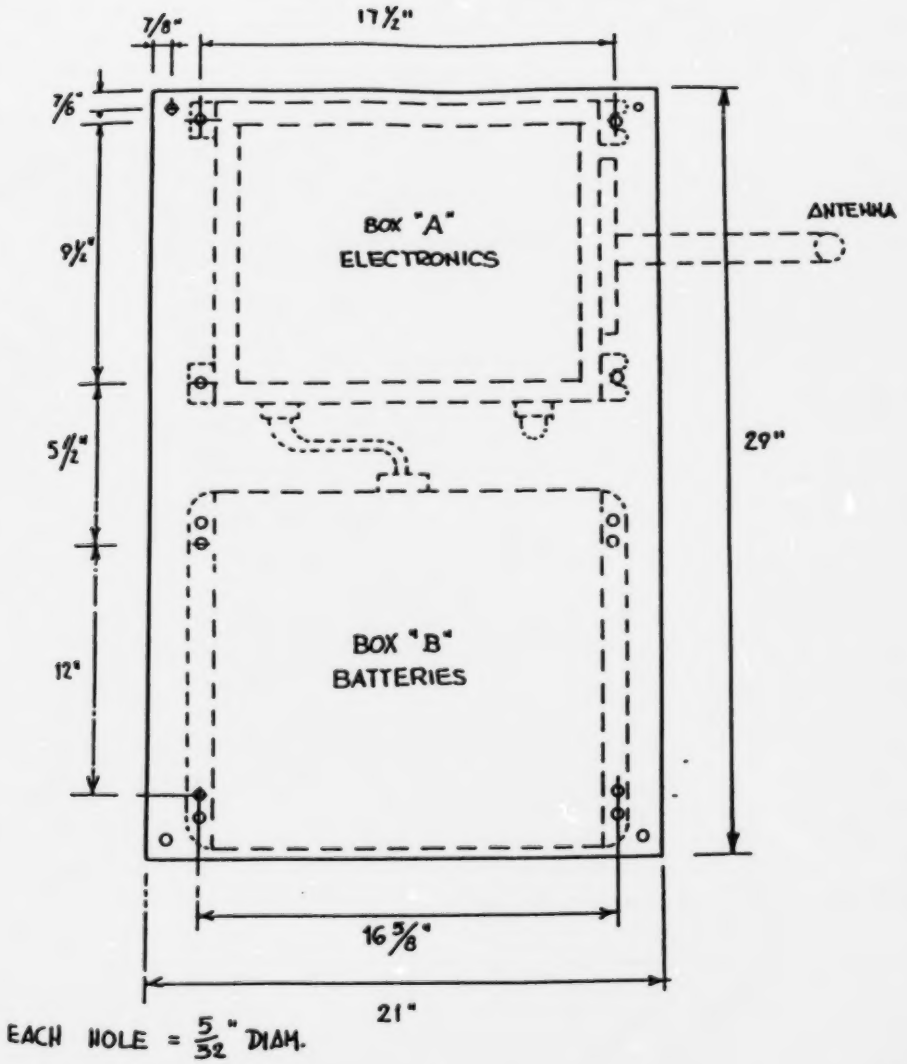


FIG.10. Design of the Carrying Platform

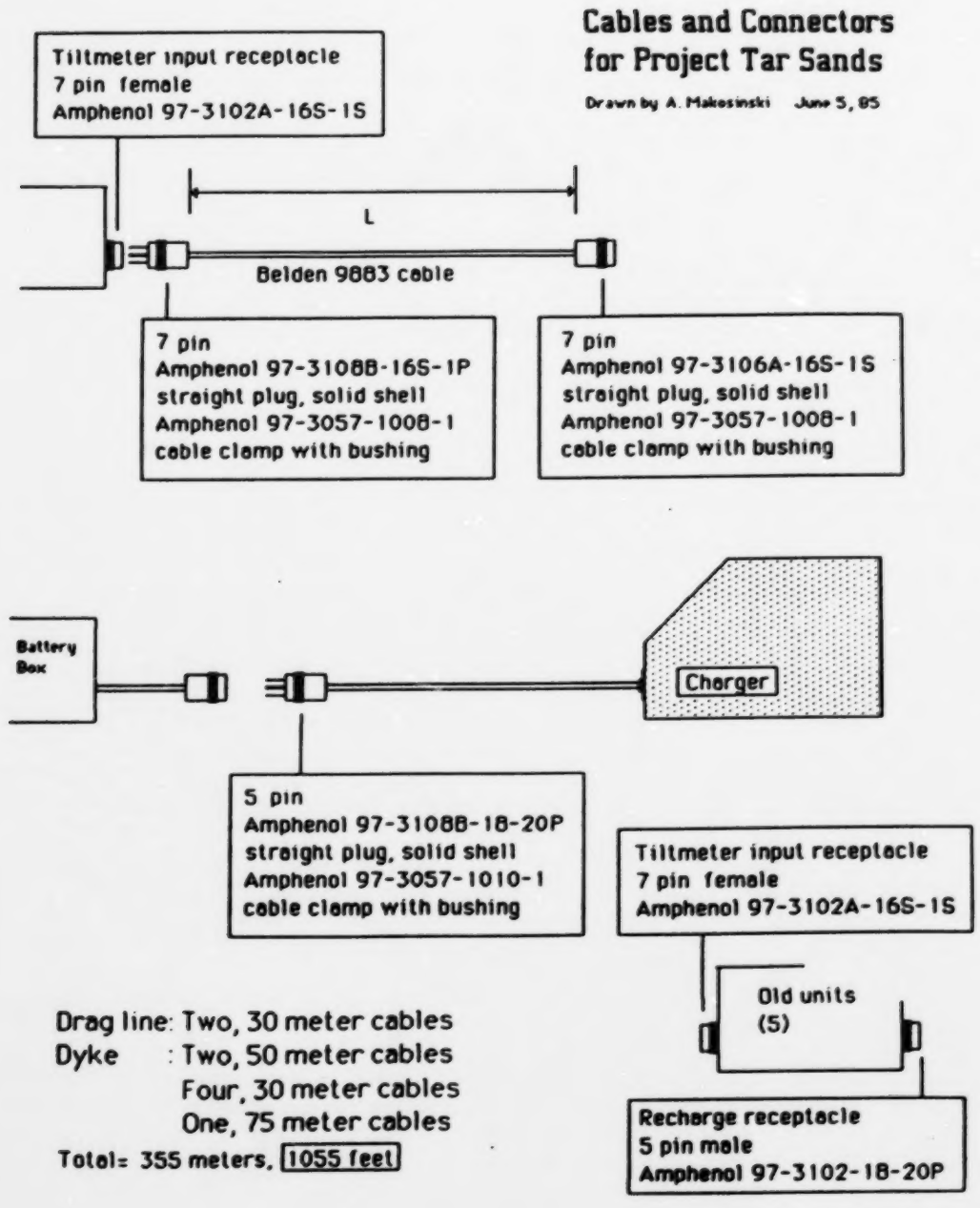


FIG.11. Design of Cable Connectors

tiltmeters and 8 slave units.

TABLE 1

Tiltmeter and Slave Calibration Parameters
(a) Tiltmeter parameters

Tiltmeter No.	Conversion Coefficient K[mV/'] Axis A	Axis B	Temperature Coefficient τ[mV/°C] Axis A	Axis B
101	0.24186	0.24189	1.0	0.0
103	0.23093	0.23129	0.0	0.0
104	0.22996	0.23122	0.4	0.7
105	0.23038	0.23138	0.0	1.0
106	0.23205	0.23017	0.4	0.4
109	1.3813	1.3800	-8.0	-10.0
108	1.3824	1.3776	3.3	14.5
107	1.3784	1.3858	1.0	4.2

(b) Slave parameters

Slave	Gain G Axis A	Axis B	Temperature drift γ[1/°C]	Offset β[mV/°C]
0	-6.24	-6.43	0.0018	-1.0
1	-5.66	-5.65	0.0012	-1.0
2	-5.73	-5.24	0.0020	-0.9
3	-6.05	-6.07	0.0012	-0.8
4	-5.59	-5.66	0.0031	1.0
5	1.0	1.0	0.0	0.0
6	1.0	1.0	0.0	0.0
7	1.0	1.0	0.0	0.0

The drift of the tilt signal may be a dangerous source of errors. Fortunately, extensive tests over 40 days have indicated that all tiltmeters except No. 109 do not have a systematic drift within the accuracy of the present system, which is about 30" (seconds of arc). The tiltmeter 109 had a drift of about 1"/day (axis A), and it has been decided not to use it in the Syncrude test.

The tilts in [mV] can be read directly at the output of the tiltmeters by using a special portable adaptor (Figure 12) and a voltmeter. In this case, the reduced tilt can be calculated in seconds of arc from:

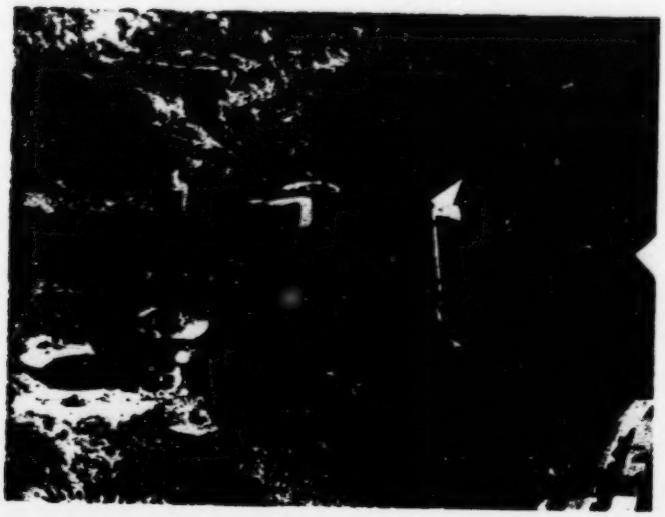


FIG.12. Tiltmeter with a Direct Readout System.

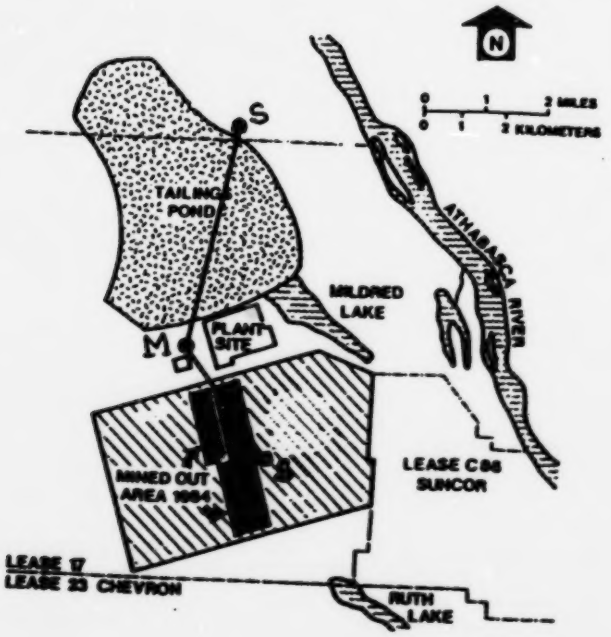


FIG.13. Approximate Locations of the Master (M) Station and of the Slaves (S) in the Preliminary Tests.

$$\alpha = (r + \tau T)/K \ ,$$

where r is the direct readout from the tiltmeter.

When using the telemetry data transmission to the master station, the computer output gives readouts of absolute tilts α in two perpendicular directions A+ and B+ in seconds of arc. The tilt values are already corrected by using the calibration parameters in the form:

$$\alpha = (r + \beta(T\text{-}25))/(K[G - \gamma(T\text{-}25)]) + \tau/K\ T + D$$

where

r = tilt signal (output from the tiltmeter) in [mV]
T = temperature
D = drift of the tilt

and other parameters as listed in Table 1.

The temperature is automatically sensed by slave units with built-in semiconductor-type temperature sensors. Due to the fact that the preparation of the slave units had to be done in Calgary (only the tiltmeters had been sent to Fredericton for their calibration) just before their installation at the test site, the Consultants could not properly calibrate the temperature sensors, particularly for a sub-zero operation. Therefore, the temperature indications could be in error by about ±2°C to ±3°C in low temperatures.

For the same reason, the electronics of the slave units, particularly the transmitters and receivers, could not be tested and adjusted for their optimal operation in temperatures below 0°C. However, the test surveys at the Syncrude site were planned for the months of August to October when very low temperatures were not expected.

5. INSTALLATION AND FIELD TESTING AT THE SYNCRUDE OPERATION

5.1 Preliminary Tests by the Consultants

The installation of the system and preliminary field tests were made between 25 and 30 August 1985.

The master station was installed in one of the offices of the Syncrude geotechnical group with two directional antennas placed on the roof of the building No. 41A. One antenna for transmitting and receiving signals from one of the draglines at a distance of about 3 km, and another directed toward the test site of tailings (6 km distance). Approximate locations of the test sites are shown on Figure 13.

5.1.1 Drag line tests

Five boreholes 3 m deep, with the aforementioned adaptors for tiltmeters, had been prepared by the Syncrude group on the bench of one of the dragline operations.

Two new slave units, No. 6 and 7, with tiltmeters 108 and 107, respectively, were used in the preliminary tests, placing the two tiltmeters equipped with the spherical adaptors (Figure 14) on the top of two neighbouring boreholes about 25 m apart and about 150 m from the dragline operation (Figure 15). Despite a strong interference by nearby VHF transmitters, strong signals were well received by the master station at the 3 km distance.

Several tests on the automatic transmission of the tilt data were performed between 27 and 29 August, with various interrogation time rates including a 14-hour test (28-29 August) with the automatic interrogation of both slaves every one hour. Both slaves responded without any interruptions. Table 2 gives a sample of the computer output from the 14-hour test. After the 14-hour period, one of the tiltmeters had to be moved in a leap-frog manner to the next borehole, farther away from the progressing dragline. The anchoring and base plate system of the tiltmeters proved to work well.

In the preliminary tests, the slave units used small omni-directional antennas (Figure 16), which proved to be sufficient for the distance of 3 km with direct visibility to the master station. However, in the future monitoring surveys, the maximum distance between the master unit and the site of the dragline operation may be as long as 5 km with some small obstacles along the line of sight. Therefore, for future tests, the Consultants decided to change the transmission omni-directional antenna in slave No. 6 into a wide angle directional antenna (Figure 17) so that a comparison of the performance of slaves No. 7 and No. 6 with different antennas could be made.

As a side product of the preliminary tests, some information has been collected on the behaviour of the shallow boreholes. If a cemented borehole could be treated as a rigid pipe, then the tilt changes recorded on the surface, ΔT in seconds of arc, could be translated into a linear relative displacement d of the ground surface with respect to the bottom of the borehole as:

$$d = \Delta T'' \, h / 206\,265'' ,$$

FIG.14. Tiltmeter Installed on a Borehole.

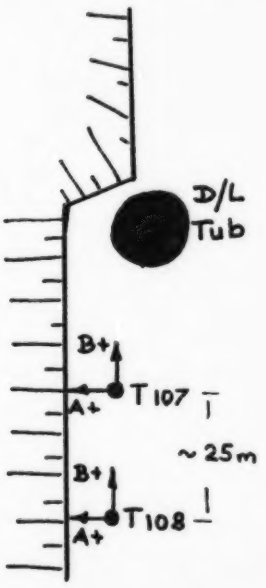


FIG.15. Locations of Tiltmeters in the Preliminary Tests (Tiltmeter T107 with Slve #7 and T108 with Slave Slave #6)

TABLE 2. SAMPLE OF THE TEST RESULTS ON THE DRAG LINE

***** SCAN STARTED		DATE: 08-29-1985			TIME: 02:21		REPETITIVE SCAN 60 MIN			
		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL	6	02:21	6	-0.00	-130	1497	4.8	13.0	-13.0	13.0	2.50
CALL	7	02:21	7	-0.04	1081	-1167	5.7	12.4	-12.4	12.4	2.42
CALL	6	02:21	6	-0.00	-129	1528	5.1	13.0	-12.9	13.0	2.50
CALL	7	02:21	7	-0.04	1081	-1167	5.7	12.4	-12.4	12.3	2.42

***** SCAN STARTED		DATE: 08-29-1985			TIME: 03:21		REPETITIVE SCAN 60 MIN			
		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL	6	03:21	6	-0.00	-131	1547	4.3	13.0	-13.0	13.0	2.50
CALL	7	03:21	7	-0.04	1165	-1253	5.1	12.4	-12.4	12.3	2.42
CALL	6	03:21	6	-0.00	-131	1550	4.6	13.0	-13.0	13.0	2.50
CALL	7	03:21	7	-0.04	1080	-1197	5.1	12.4	-12.4	12.3	2.42

***** SCAN STARTED		DATE: 08-29-1985			TIME: 04:21		REPETITIVE SCAN 60 MIN			
		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL	6	04:21	6	-0.00	-103	1491	4.3	13.0	-13.0	13.0	2.50
CALL	7	04:21	7	-0.04	1052	-1140	5.1	12.4	-12.4	12.3	2.42
CALL	6	04:21	6	-0.00	-75	1519	4.3	13.0	-12.9	13.0	2.50
CALL	7	04:21	7	-0.04	1080	-1197	5.1	12.3	-12.4	12.3	2.42

***** SCAN STARTED		DATE: 08-29-1985			TIME: 05:21		REPETITIVE SCAN 60 MIN			
		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL	6	05:21	6	-0.00	-131	1491	4.3	13.0	-13.0	13.0	2.50
CALL	7	05:21	7	-0.04	1024	-1169	5.1	12.4	-12.4	12.3	2.42
CALL	6	05:21	6	-0.00	-160	1547	4.3	13.0	-12.9	13.0	2.50
CALL	7	05:21	7	-0.04	1080	-1169	5.1	12.3	-12.4	12.3	2.42

***** SCAN STARTED		DATE: 08-29-1985			TIME: 06:21		REPETITIVE SCAN 60 MIN			
		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL	6	06:21	6	-0.00	-131	1491	4.3	13.0	-13.0	13.0	2.50
CALL	7	06:21	7	-0.04	1052	-1168	5.4	12.4	-12.4	12.3	2.42
CALL	6	06:21	6	-0.00	-160	1519	4.3	13.0	-12.9	13.0	2.50
CALL	7	06:21	7	-0.04	1024	-1196	5.4	12.3	-12.4	12.3	2.42

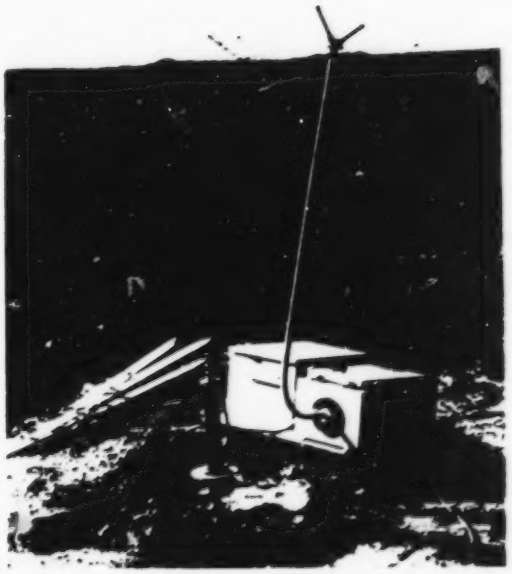


FIG.16. One of the New Slaves with the Omni--directional Antenna

FIG.17. A Directional Antenna mounted on the Slave.

or $\Delta T''$ could be interpreted as a rigid body rotation of the whole block in which the borehole is located. As already mentioned, the present system with the tiltmeters gives the tilt resolution of about 30" which corresponds to the relative linear displacement of 0.4 mm for a 3 m deep borehole. In the aforementioned 14-hour test, the following overall tilt changes and corresponding displacement values were obtained:

slave No. 6: -67" (1 mm) in the direction A+ and -8" (0.1 mm) in B+ axis; and
slave No. 7: -58" (0.9 mm) in A+ direction and +38" (-0.5 mm) in B+ direction.

(The signs + of the tilt correspond to the upward tilt of the given axis.)

In an earlier test (27 August) of a total of 7 hours duration with interrogation intervals varying from 5 to 15 minutes, the total ($\sqrt{A^2 + B^2}$) temporal tilt changes as large as 436" (6.3 mm) at slave No. 7 and 355" (5.3 mm) at slave No. 6 were recorded. During the first two hours of that test, the dragline was walking. Also a dozer was working for some time in the vicinity of the tiltmeters. The overall tilt changes in the 7-hour test were much smaller: 167" (2.4 mm) at slave No. 7 and 59" (0.9 mm) at slave No. 6.

5.1.2 Tailings tests

Three *old* slaves, Nos. 0, 1, and 4, with tiltmeters 101, 104, and 105, were assigned for the stationary tests at the selected profile of the tailings dyke, about 6 km away from the location of the master station. Due to a lack of direct visibility between the slaves and the directional antenna of the master station, some problems arose in obtaining clear signals from the slaves even when the slaves were located on top of the dyke. The tiltmeters could not be connected to the slaves because their locations had not been prepared by the Syncrude Tailings Group. After additional adjustments, two stations, No. 0 and No. 4, started responding to the master commands. However, after relocating the slaves behind the crest of the dyke no signals were obtained. It was decided to replace the small transmitting omni-directional antennas in slaves No. 0 and No.4 by wide angle directional antennas which improved the transmission of the signals if the slaves were not more than 2 to 3 m below the crest of the dyke. If lowered further, no signals could be obtained.

As a result of the preliminary tests, it was decided that in the future tests on the tailings site the slave stations should be placed near the crest of the dyke while the tiltmeters of the monitoring stations would be connected to the slave units by cables of up to 150 m in length, as designed by the Consultants.

The overall preliminary test could be considered a success, considering the long distance involved and the lack of direct intervisibility.

5.2 Tests by the Syncrude Group

On 30 August 1985, the Consultants gave a seminar on the use of the telemetry system to the Syncrude geotechnical engineers of both the dragline and tailings operations. The seminar was followed by a brief training session in the use of the system so that the Syncrude group could perform additional tests on their own.

At the time of writing this report (February 1986), the telemetry system is still installed at the Syncrude site and, according to personal communications between the Consultants and the Syncrude Group (mainly Mr. Steve Tan), intensive tests are being conducted at the dragline

operation.

On 25 November 1985, the Syncrude group submitted to Dr. Fisekci of CANMET a preliminary assessment of the telemetry system in the form of a progress report which is attached in full as Appendix A. The report deals only with tests on the dragline operation. The attached Appendix A results indicate that the system has worked well in temperatures down to about -20°C (within the ±3°C accuracy of the sensors) as anticipated.

Very recent communications (February 1986) with Mr. Tan have revealed that some problems have been encountered with the automatic interrogations of slaves at pre-programmed time intervals. The Consultants believe that the problem has been caused by a power failure when the system was turned on which could have destroyed the computer file. This will be clarified after obtaining the file diskette from Syncrude.

In general, the tests at the dragline operation seem to be progressing well. No information has been obtained by the Consultants from the tailings group.

6. GENERAL CONCLUSIONS AND RECOMMENDATIONS

The performed tests have proven that generally the present telemetry system can be successfully used in the environment of the oil sands mining.

The quotation from the letter (Appendix A) by A. Fair of Syncrude to CANMET summarizes the evaluation of the telemetry system:

> *The system has two big advantages to the current slope monitoring system. First, there is an opportunity to substantially reduce the amount of labour and time required to utilize our current system. Secondly, the telemetry system will provide an opportunity to obtain continuous data. In our opinion, the system has tremendous potential and is definitely worthy of further testing.*

In order to make the present system fully applicable to the needs of Syncrude Canada Ltd., the Consultants recommend:

1. That the system be modified to allow for connecting several sensors to each slave. In the opinion of the Consultants, the monitoring of the surface movements alone on the dragline bench is not sufficient for the detection of the block slides. Therefore, several sensors at various depths must be used in the monitoring scheme. The selection of the type of sensors to be used requires a separate study. However, any type of sensor can be adapted to the present telemetry system with minor modifications. The system can be easily modified (minor hardware and software changes) to adapt 6 sensors for each slave. If more sensors would be required, then major changes to the system would have to be made.

2. That an alert system be built in so that each slave could alarm the master station when any of the sensors would indicate abnormal or beyond tolerance behaviour of the monitored phenomena. The alarm system would require extensive software changes and hardware additions (see the ERCL final report 1983) but it would not affect the basic operation of the system.

3. That an antenna relay system be built in to each slave so that any type of omni or directional antenna could be used to serve (one antenna per slave) both the transmitter and the receiver. In order to minimize the need for the use of the bulky directional antennas, more powerful transmitters could be used with the system. This would decrease the life of the batteries.

4. That heaters be built in for the transceivers in order to lower the working temperature limit to -40°C. The transceivers are the most sensitive components of the telemetry system as far as the low temperature is concerned. The Consultants believe that other components could work in temperatures lower than -25°C but the transceivers require a heating element. This would require minor modifications and a slightly (about 15%) decreased life of the batteries.

5. That the data processing software at the master be changed so that the information on the monitored ground movements would be readily displayed in a more comfortable format (preferably in a graphical form). This would not require any hardware changes to the system.

The above modifications can be made by the Consultants, if requested.

One should point out that the present system was designed in 1980. The technological progress of the last six years would allow for constructing a much more advanced new telemetry

system which could handle hundreds of sensors instantaneously.

REFERENCES

Ecological and Resources Consultants Ltd. (1980). "Development, installation and operation of a subsidence monitoring and telemetry system." Final contract report submitted to CANMET (DSS File: 18SQ.23440-8-0-16, Contract Serial No. 0SQ78-00238).

Ecological and Resources Consultants Ltd. (1983). "Maintenance, construction and installation of an additional system, and research on further improvements and extended applications of the subsidence monitoring and telemetry system." Final contract report submitted to CANMET (DSS File 18SQ.23440-1-9131, contract serial no. 0SQ82-00051).

Fair, A.E. and B.A. Isaac (1985). "Highwall stability monitoring at Syncrude Canada Ltd. open pit mining operation." Reprint of a conference paper (the name of the conference was not given on the reprint).

Fair, A.E. and E.R.F. Lord (1984). "Methods used to monitor and control block slides in oilsands at Syncrude's dragline operation in northern Alberta, Canada." Fourth International Symposium on Landslides, I.S.S.M.F.E., Toronto.

APPENDIX A

PRELIMINARY ASSESSMENT PROGRESS REPORT

by

SYNCRUDE CANADA LTD.

Syncrude Canada Ltd. P.O. Bag 4009, Ft. McMurray, Alberta, Canada T9H 3L1 Telephone (403) 791 5011

ENERGY, MINES & RESOURCES
CANADA

0488J

NOV 29 1985

CANMET
Calgary Coal Research Laboratory

Nov. 25, 1985

ENERGY, MINES AND RESOURCES CANADA
CANMET
4500 - 16TH AVE N.W.
CALGARY, ALBERTA
T3B 0M6

ATTENTION: M.Y. FISEKCI

Dear Yilmaz:

SUBJECT: TILTMETER/TELEMETRY SYSTEM PRELIMINARY ASSESSMENT - PROGRESS REPORT

I have enclosed a copy of a Syncrude internal report entitled 'Tiltmeter/Telemetry System Preliminary Assessment - Progress Report' for your information and files. The report references our current two phase evaluation program of the CANMET/U.N.B. tiltmeter/telemetry system and some of the preliminary results. The first phase, which has been completed, involved an initial short-term assessment of the system. The second phase will involve a longer term evaluation period. In addition, the system is also being experimented with in the Tailings area in an effort to monitor a sensitive area along the east-side dyke.

Our preliminary assessment indicated the need to upgrade the current directional antenna system and possibly the need for a stronger transmission unit. The directional antenna will limit the slave station portability in the field at the Syncrude site. Some software modifications may also be beneficial in terms of allowing built-in alarms and more sophisticated data presentation formats. The versatility of the system would be enhanced considerably by modifying the slave and/or master stations to be compatible with other type of sensors, particularly the slope inclinometer system.

The system has two big advantages to the current slope monitoring system. First, there is an opportunity to substantially reduce the amount of labour and time required to utilize our current system.

...2/

Secondly, the telemetry system will provide an opportunity to obtain continuous data. In our opinion, tne system has tremendous potential and is definitely worthy of further testing.

We would like the opportunity to continue our evaluation program, although we understand that an extension of the current contract is necessary to continue the program. Can you please advise us if this can be arranged? In addition, we would suggest that we further discuss the aforementioned modifications in terms of the feasibility and cost implications. If you require any additional information please feel free to contact me at (403) 790-5359.

Yours truly,

SYNCRUDE CANADA LTD.

A.E. Fair,
Supervisor,
Geotechnical Eng.

AEF/jmd

Enclosure

cc: A. Chrzanowski
S. Tan

TILTMETER/TELEMETRY SYSTEM PROGRESS REPORT

INTRODUCTION

Due to the increased demand for mine production at Syncrude, the Geotechnical Engineering Section is presently attempting to enhance its highwall monitoring program through a research and development program. Under this program we wish to provide a reliable and safe method of dragline/highwall monitoring, provide faster data turnaround time, and decrease both manpower requirements and the interruption of dragline operating time when reading instrumentation.

One of the systems presently being evaluated is the tiltmeter/telemetry system supplied by CANMET and designed by the University of New Brunswick. The following report is intended to provide a brief preliminary assessment of our current testing program for this unit.

OBJECTIVES

The purpose of this testing program is basically to evaluate two separate systems:

1) The tiltmeter system is designed to detect surface movement, therefore our first goal is to determine if detection of surface movement is feasible under our unique tarsand mining environment. If so, this system could be considered as a possible supplement to our present slope inclinometer system.

2) If the telemetry system can demonstrate the ability to both transmit and receive slope monitoring data reliably and consistently, it could potentially result in a considerable overall improvement to a present slope monitoring program. The system would result in reduced slope monitoring manpower requirements and an opportunity to obtain 'continuous' data.

...2/

FIELD TESTING PROGRAM

A two phase field program is required to evaluate the viability of the tiltmeter/telemetry system.

Phase 1 provides a short term test of the equipment for approximately a one or two week period, under winter and summer conditions. A trial setup was initiated on Sept. 30/85, in which six (6) stations anchored to a three (3) meter depth were installed with a 25 meter spacing just north of an operating dragline (see Fig. 1). Two tiltmeter/slave stations were set up on the stations closest to the dragline and 'leapfrogged' north as the dragline mined the area (see Fig. 2 for installation specs).

The two slave stations were located next to one tiltmeter location, with a 30 meter extension lead connected to the second tiltmeter (one tiltmeter per slave). A total of twenty (20) scans (reading sequences) were recorded, at two hour intervals, for this test period. A listing of each scan reading is provided in the Appendix.

Moving one tiltmeter to its second location was completed by one field monitor/engineer in approximately 10-15 minutes, while relocating one tiltmeter plus two slave stations required two field monitors/engineers and took approximately 15-20 minutes.

Initially the tiltmeter system would not transmit from the slave stations over the distance of approximately 6 Km. A larger directional antenna was obtained and connected to each slave for proper transmission/reception of the data.

...3/

CONCLUSIONS & RECOMMENDATIONS

During this short term test period, the following observations, conclusions and recommendations were noted:

1) The relocation of tiltmeters and slaves can be completed relatively easily and quickly in the field.

2) Telemetry transmission of data required stronger directional antennas.

3) The variance, or change in tilt, over a relatively consistent set of readings (scans 1-12) indicate surface movement in Slave #6 of 1.4mm and 2.4mm for the A and B axis respectively; and -2.5mm and -2.8mm for the A and B axis of Slave #7, as indicated in Table 1.

4) The temperature variance between Tiltmeter #6 and #7 averaged approximately $2^{o}C$. The instruments were located within 25m of each other during this period. (Note the temperature variance for each scan is circled in the printout).

5) A marked changed in readings occurred in scan #3, for which there was no apparent reason.

6) A power failure occurred between scan 13 & 14, as indicated on the scan printout, at which time the time for scan 14 started at zero. Unless the time of the start up scan is recorded manually, there is no way of determining the elapsed time between the power off/power on scans.

7) Scans 14 through 20 indicated a marked fluctuation in the tilt A readings for Slave #7, for which no apparent reason is evident.

...4/

8) In a recent telemetry test (Nov. 23, 1985), the system was programmed to take repetative scans every three hours (360 min.), as indicated in scans 30 to 36 (see appendix). For no apparent reason, the system reprogramned itself for a six (6) minute repetative scan after scan 32.

9) The battery charge for both slaves remained relatively constant and unaffected throughout the test period.

10) Assuming that surface tiltmeters provide a reliable indication of sub-surface movement, the installation depth "d", which was set at 3 meters for this test program, will require further testing at various depths to determine the optimum installation depth required to detect the sub-surface movement.

11) Future consideration should be given to enhancing the present slave/telemetry system, as well as the PC programming, to incorporate monitoring of the present slope inclinometer traversing probe and the new borehole deflectometer system (BDS) presently in its testing stages.

Phase II of the testing program will be conducted over a longer time duration (approximately one month) in an area of known movement and isolated from daily mine equipment interference. This will allow the installation of tiltmeter/slave stations located within 5 to 10 feet of a slope indicator installation, to enable the comparison of surface/sub-surface movement.

Controlled tests can than be initiated to monitor surface equipment interference, power interruptions and the reaction of frozen soil (winter) as opposed to unfrozen soil (summer).

Under the above field conditions, a complete set of data can be collected for further evaluation of the system.

Terry Stevens

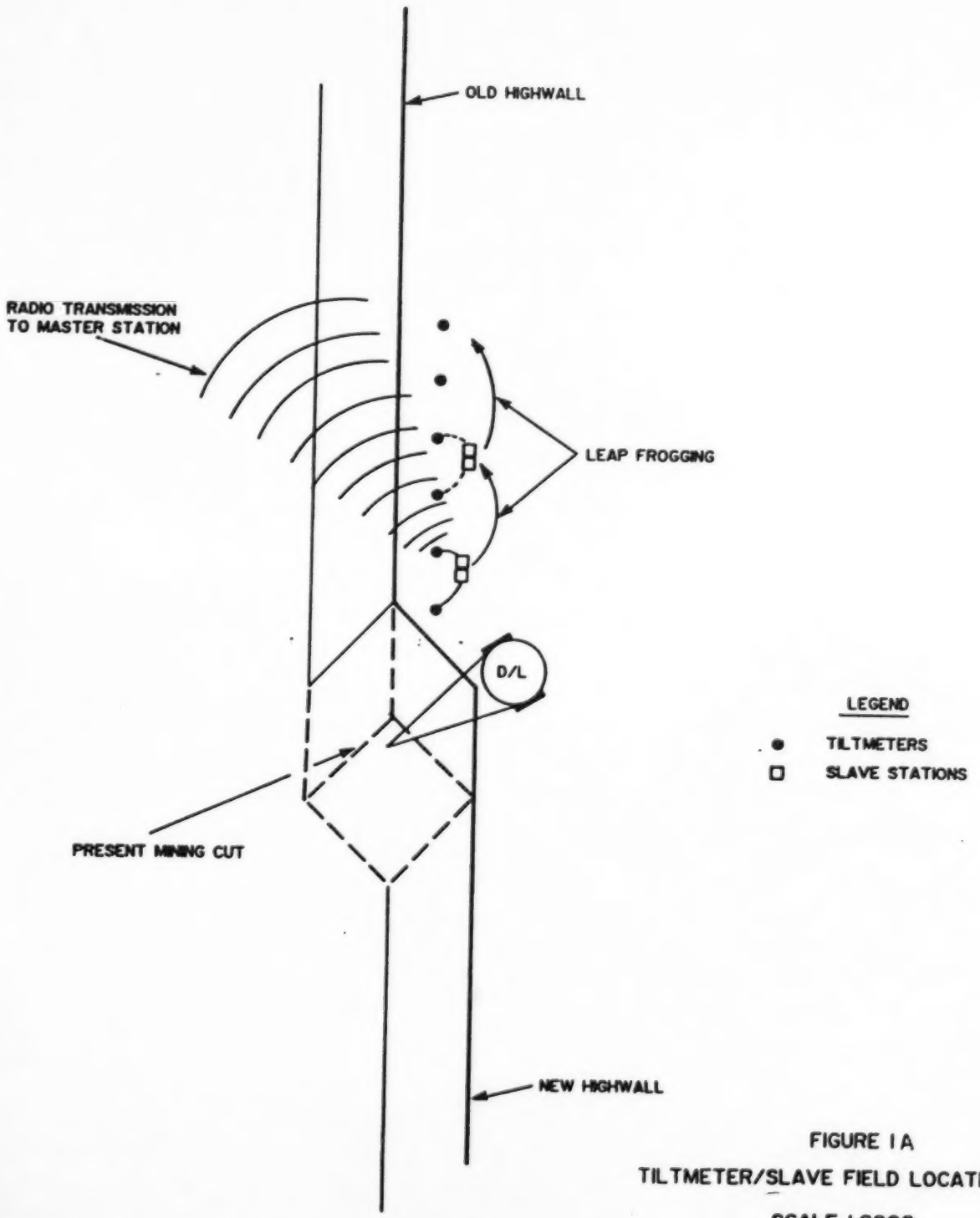
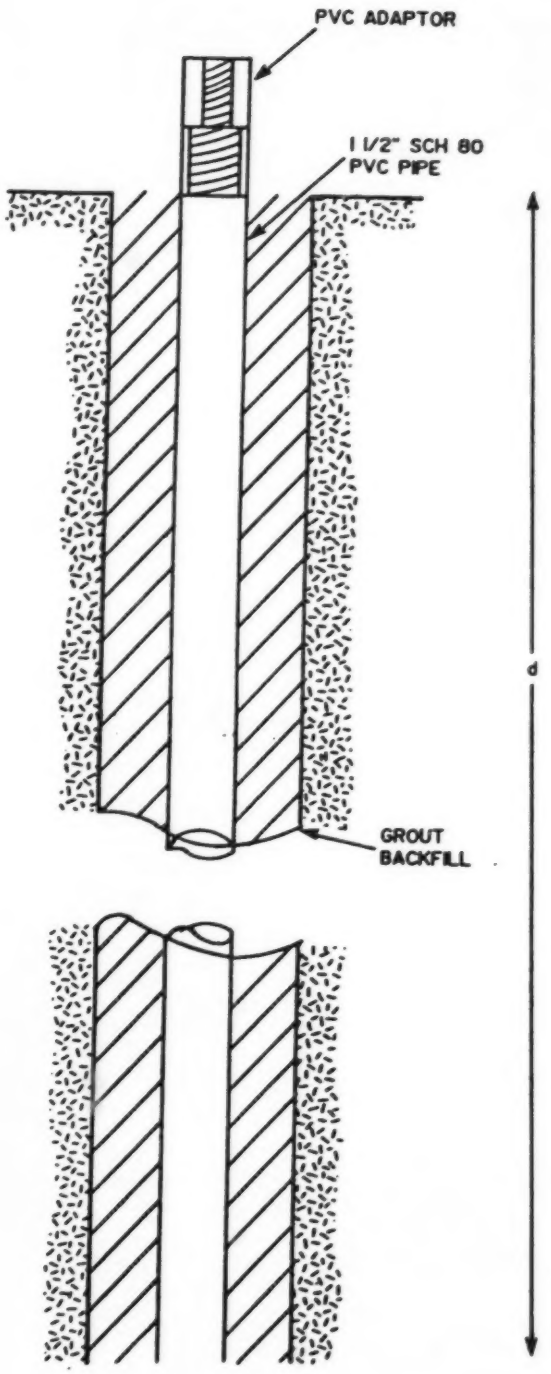


FIGURE 1A

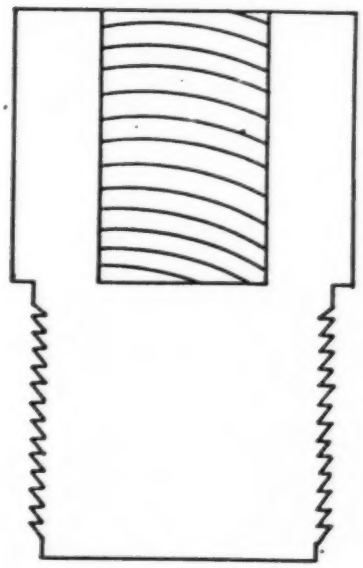
TILTMETER/SLAVE FIELD LOCATION MAP

SCALE 1:2000



SCALE 1:5

PVC ADAPTOR



FULL SCALE

NOTE: d= INSTALLATION DEPTH = 3 METERS

TILTMETER THREADED INTO PVC ADAPTOR

FIGURE 2A

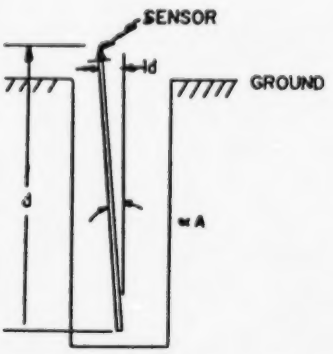
TILTMETER STATION INSTALLATION DIAGRAM

TABLE I

LINEAR DISTANCE CALCULATION

$$ld = \frac{\sim A \text{ (SECONDS OF ARC)} \times d \text{ (mm)}}{180° \times 60' \times 60'' \text{ (SECONDS OF ARC)}}$$

$$ld = \frac{\sim A \text{ (SECONDS)} \times d \text{ (mm)}}{206264}$$



WHERE :
- ~A = TILT ANGLE
- ld = EQUIVALENT LINEAR DISTANCE
- d = INSTALLATION DEPTH

TOTAL CHANGE IN TILT
(COMPARISON SCAN 1-12)

SLAVE 6

TILT A:

$$ld = \frac{[-280-(-378)]\ 300}{206264} = +1.4\text{mm}$$

TILT B:

$$ld = \frac{[+1370-(1208)]\ 300}{206264} = +2.4\text{mm}$$

SLAVE 7

TILT A:

$$ld = \frac{[+1196-(1370)]\ 300}{206264} = -2.5\text{mm}$$

TILT B:

$$ld = \frac{[+1034-(1225)]\ 300}{206264} = -2.8\text{mm}$$

APPENDIX

SCAN DATA

```
***** SCAN STARTED  DATE: 09-30-1985   TIME: 16:19   REPETITIVE SCAN  120 MIN
                TIME      ID     CHO    TILTA    TILTB    TEMP    +VB1    -VB2    +VB3    TES
1  CALL  6    16:19       6   -0.00     -325     1208    17.8    12.8   -12.7    12.3    2.5
   CALL  7    16:19
              OVF XRE0     7   -0.04     1345     1155    18.3    12.3   -12.3    11.8    2.4

MAINTENANCE STATISTICS     DATE: 09-30-1985   TIME: 16:19
OVERFLOW    7( 1)
ORIG.CALLS 6( 2) 7( 2)

***** SCAN STARTED  DATE: 09-30-1985   TIME: 18:19   REPETITIVE SCAN  120 MIN
                TIME      ID     CHO    TILTA    TILTB    TEMP    +VB1    -VB2    +VB3    TES
2  CALL  6    18:19       6   -0.00     -337     1211    12.7    12.9   -12.8    12.3    2.5
   CALL  7    18:19       7   -0.04     1370     1225    13.6    12.3   -12.4    11.8    2.4

MAINTENANCE STATISTICS     DATE: 09-30-1985   TIME: 18:19
OVERFLOW    7( 1)
ORIG.CALLS 6( 3) 7( 3)

***** SCAN STARTED  DATE: 09-30-1985   TIME: 20:19   REPETITIVE SCAN  120 MIN
                TIME      ID     CHO    TILTA    TILTB    TEMP    +VB1    -VB2    +VB3    TES
3  CALL  6    20:19       6   -0.00     -374     1229     9.1    12.9   -12.8    12.3    2.5
   CALL  7    20:19       7   -0.04     1339     1187    10.5    12.3   -12.3    11.8    2.4

MAINTENANCE STATISTICS     DATE: 09-30-1985   TIME: 20:19
OVERFLOW    7( 1)
ORIG.CALLS 6( 4) 7( 4)

***** SCAN STARTED  DATE: 09-30-1985   TIME: 22:19   REPETITIVE SCAN  120 MIN
                TIME      ID     CHO    TILTA    TILTB    TEMP    +VB1    -VB2    +VB3    TES
4  CALL  6    22:19       6   -0.00     -378     1243     7.6    12.9   -12.8    12.3    2.5
   CALL  7    22:19       7   -0.04     1338     1184     9.3    12.3   -12.3    11.8    2.4

MAINTENANCE STATISTICS     DATE: 09-30-1985   TIME: 22:19
OVERFLOW    7( 1)
ORIG.CALLS 6( 5) 7( 5)

***** SCAN STARTED  DATE: 10-01-1985   TIME: 00:19   REPETITIVE SCAN  120 MIN
                TIME      ID     CHO    TILTA    TILTB    TEMP    +VB1    -VB2    +VB3    TES
5  CALL  6    00:19       6   -0.00     -376     1229     8.2    12.9   -12.8    12.3    2.5
   CALL  7    00:19       7   -0.04     1367     1186    10.3    12.3   -12.3    11.8    2.4

MAINTENANCE STATISTICS     DATE: 10-01-1985   TIME: 00:19
OVERFLOW    7( 1)
ORIG.CALLS 6( 6) 7( 6)

***** SCAN STARTED  DATE: 10-01-1985   TIME: 02:19   REPETITIVE SCAN  120 MIN
                TIME      ID     CHO    TILTA    TILTB    TEMP    +VB1    -VB2    +VB3    TES
6  CALL  6    02:19       6   -0.00     -374     1227     7.1    12.9   -12.8    12.3    2.5
   CALL  7    02:19       7   -0.04     1339     1187     8.9    12.3   -12.3    11.8    2.4

MAINTENANCE STATISTICS     DATE: 10-01-1985   TIME: 02:19
OVERFLOW    7( 1)
ORIG.CALLS 6( 7) 7( 7)
```

***** SCAN STARTED DATE: 10-01-1985 TIME: 04:

	TIME	ID	CH0	TILTA			+VB3	VB2
CALL 6	04:19	6	-0.00			1220		
CALL 7	04:19							

(1.7)

MAINTENANCE

								12.8		2.50
								12.3	7	2.42

(1.7)

TIME: 08:19

TIME: 08:19 REPETITIVE SCAN 120 MIN

	TIME	ID	CH0	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL 6		6	-0.00	-353	1225	6.0	12.9	-12.8	12.3	2.50
CALL 7	08:19	7	-0.04	1337	1208	7.9	12.3	-12.3	11.7	2.42

(1.9)

MAINTENANCE STATISTICS DATE: 10-01-1985 TIME: 08:19
OVERFLOW 7(1)
ORIG.CALLS 6(10) 7(10)

***** SCAN STARTED DATE: 10-01-1985 TIME: 10:19 REPETITIVE SCAN 120 MIN

	TIME	ID	CH0	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL 6	10:19	6	-0.00	-324	1370	6.2	12.8	-12.8	12.3	2.50
CALL 7	10:19	7	-0.04	1196	1040	8.5	12.3	-12.3	11.7	2.42

(2.3)

MAINTENANCE STATISTICS DATE: 10-01-1985 TIME: 10:19
OVERFLOW 7(1)
ORIG.CALLS 6(11) 7(11)

***** SCAN STARTED DATE: 10-01-1985 TIME: 12:19 REPETITIVE SCAN 120 MIN

	TIME	ID	CH0	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL 6	12:19	6	-0.00	-312	1227	11.6	12.9	-12.8	12.3	2.50
CALL 7	12:19	7	-0.04	1258	1034	15.8	12.3	-12.3	11.8	2.42

(4.2)

MAINTENANCE STATISTICS DATE: 10-01-1985 TIME: 12:19
OVERFLOW 7(1)
ORIG.CALLS 6(12) 7(12)

***** SCAN STARTED DATE: 10-01-1985 TIME: 14:19 REPETITIVE SCAN 120 MIN

	TIME	ID	CH0	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL 6	14:19	6	-0.00	-280	1327	13.4	12.9	-12.7	12.3	2.50
CALL 7	14:19	7	-0.04	1257	1060	15.4	12.3	-12.4	11.8	2.42

(2.0)

MAINTENANCE STATISTICS DATE: 10-01-1985 TIME: 14:19
OVERFLOW 7(1)
ORIG.CALLS 6(13) 7(13)

***** SCAN STARTED DATE: 10-01-1985 TIME: 16:19 REPETITIVE SCAN 120 MIN

	TIME	ID	CH0	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL 6		6	-0.00	30	2090	12.7	12.9	-12.8	12.3	2.50
CALL 7		7	-0.04	1257	1114	14.1	12.3	-12.4	11.8	2.42

(1.4)

MAINTENANCE STATISTICS DATE: 10-01-1985 TIME: 16:19
OVERFLOW 7(1)
ORIG.CALLS 6(14) 7(14)

← POWER FAILURE

***** SCAN STARTED DATE: 01-01-1980 TIME: 00:01 REPETITIVE SCAN 120 MIN

		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
14 CALL	6	00:01	6	-0.00	-219	-495	15.0	12.9	-12.8	12.3	2.50
CALL	7	00:02	7	-0.04	182	814	17.5	12.4	-12.4	11.8	2.42

(2.5)

MAINTENANCE STATISTICS DATE: 01-01-1980 TIME: 00:01
ORIG.CALLS 6(1) 7(1)

***** SCAN STARTED DATE: 01-01-1980 TIME: 02:01 REPETITIVE SCAN 120 MIN

		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
15 CALL	6	02:01	6	-0.00	-216	-483	16.1	12.9	-12.8	12.3	2.50
CALL	7	02:02	7	-0.04	98	-86	18.3	12.4	-12.4	11.8	2.42

(2.2)

MAINTENANCE STATISTICS DATE: 01-01-1980 TIME: 02:01
ORIG.CALLS 6(2) 7(2)

***** SCAN STARTED DATE: 01-01-1980 TIME: 04:01 REPETITIVE SCAN 120 MIN

		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
6 CALL	6	04:01	6	-0.00	-215	-480	16.4	12.9	-12.8	12.3	2.50
CALL	7	04:02	7	-0.04	98	-86	18.3	12.4	-12.4	11.8	2.42

(1.9)

MAINTENANCE STATISTICS DATE: 01-01-1980 TIME: 04:01
ORIG.CALLS 6(3) 7(3)

***** SCAN STARTED DATE: 01-01-1980 TIME: 06:01 REPETITIVE SCAN 120 MIN

		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
7 CALL	6	06:01	6	-0.00	-217	-486	15.8	12.9	-12.7	12.3	2.50
CALL	7	06:02	7	-0.04	183	815	17.8	12.4	-12.4	11.8	2.42

(2.0)

MAINTENANCE STATISTICS DATE: 01-01-1980 TIME: 06:01
ORIG.CALLS 6(4) 7(4)

***** SCAN STARTED DATE: 01-01-1980 TIME: 08:01 REPETITIVE SCAN 120 MIN

		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
9 CALL	6	08:01	6	-0.00	-217	-489	15.5	12.9	-12.7	12.3	2.50
CALL	7	08:02	7	-0.04	182	814	17.5	12.4	-12.4	11.8	2.42

(2.0)

MAINTENANCE STATISTICS DATE: 01-01-1980 TIME: 08:01
ORIG.CALLS 6(5) 7(5)

***** SCAN STARTED DATE: 01-01-1980 TIME: 10:01 REPETITIVE SCAN 120 MIN

		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL	6	10:01	6	-0.00	-219	-495	15.0	12.9	-12.8	12.3	2.50
CALL	7	10:02	7	-0.04	182	840	16.9	12.4	-12.4	11.8	2.42

(1.9)

MAINTENANCE STATISTICS DATE: 01-01-1980 TIME: 10:01
ORIG.CALLS 6(6) 7(6)

***** SCAN STARTED DATE: 01-01-1980 TIME: 12:01 REPETITIVE SCAN 120 MIN

		TIME	ID	CHO	TILTA	TILTB	TEMP	+VB1	-VB2	+VB3	TEST
CALL	6	12:01									
		ERR XREQ									
CALL	7	12:02	7	-0.04	182	814	17.4	12.9	-12.8	12.3	2.50
							17.4	12.3	-12.4	11.8	2.42

(2.0)

MAINTENANCE STATISTICS DATE: 01-01-1980 TIME: 12:01
LRC ERROR 6(1)
ORIG.CALLS 6(7) 7(7)

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                TIME        ID     CH0   TILTA   TILTB    TEMP    +VB1    -VB2    +VB3
CALL   6    06:31         6   -0.00   -1151     351   -20.5    12.7   -12.8    12.7
CALL   7    06:31
            TIM CALL
            TIM CALL
            TIM CALL
            DIAGNOST -192    4.96    4.96    4.96    4.96    4.96    4.96    4.96
CALL   6    06:32         6   -0.00   -1150     354   -20.2    12.5   -12.8    12.7
CALL   7    06:32
            TIM CALL
            TIM CALL
            TIM CALL
            DIAGNOST -192    4.96    4.96    4.96    4.96    4.96    4.96    4.96

MAINTENANCE STATISTICS     DATE: 11-23-1985   TIME: 06:31
TIME OUT    6( 4) 7(41) 6( 4) 7(41)
TIM-S OUT   6( 2) 7( 2) 6( 2) 7( 2)
LRC ERROR   7( 5) 7( 5)
OVERFLOW    6( 1) 7( 6) 6( 1) 7( 6)
PERM ERROR 6( 2) 7(18) 6( 2) 7(18)
ORIG.CALLS 6(18) 7(18) 6(18) 7(18)

31  ***** SCAN STARTED  DATE: 11-23-1985   TIME: 12:31   REPETITIVE SCAN  360 M
                TIME        ID     CH0   TILTA   TILTB    TEMP    +VB1    -VB2    +VB3
CALL   6    12:31
            ERR XREQ      6   -0.00   -1170     364   -16.5    12.7   -12.8    12.7
CALL   7    12:31         7   -0.04     868   -2014   -13.4    12.4   -12.4    11.5
CALL   6    12:31         6   -0.00   -1170     364   -16.5    12.5   -12.7    12.7
CALL   7    12:31         7   -0.04     897   -1986   -13.4    12.3   -12.4    11.5

MAINTENANCE STATISTICS     DATE: 11-23-1985   TIME: 12:31
TIME OUT    6( 4) 7(41) 6( 4) 7(41)
TIM-S OUT   6( 2) 7( 2) 6( 2) 7( 2)
LRC ERROR   6( 1) 7( 5) 6( 1) 7( 5)
OVERFLOW    6( 1) 7( 6) 6( 1) 7( 6)
PERM ERROR 6( 2) 7(18) 6( 2) 7(18)
ORIG.CALLS 6(20) 7(20) 6(20) 7(20)

32  ***** SCAN STARTED  DATE: 11-23-1985   TIME: 18:31   REPETITIVE SCAN  360 M
                TIME        ID     CH0   TILTA   TILTB    TEMP    +VB1    -VB2    +VB3
CALL   6    18:31         6   -0.00   -1175     369   -18.8    12.7   -12.8    12.8
CALL   7    18:31
            TIM CALL
            TIM CALL
            TIM CALL
            DIAGNOST -192    4.96    4.96    4.96    4.96    4.96    4.96    4.96
CALL   6    18:32
            TIM CALL
            TIM CALL
            TIM CALL
            DIAGNOST -192    4.96    4.96    4.96    4.96    4.96    4.96    4.96
CALL   7    18:33
            TIM CALL
            TIM CALL
            TIM CALL
            DIAGNOST -192    4.96    4.96    4.96    4.96    4.96    4.96    4.96

MAINTENANCE STATISTICS     DATE: 11-23-1985   TIME: 18:31
TIME OUT    6( 7) 7(47) 6( 7) 7(47)
TIM-S OUT   6( 2) 7( 2) 6( 2) 7( 2)
LRC ERROR   6( 1) 7( 5) 6( 1) 7( 5)
OVERFLOW    6( 1) 7( 6) 6( 1) 7( 6)
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CALL  6   18:35
          TIM CALL
          TIM CALL
          TIM CALL
          DIAGNOST -192   4.96   4.96   4.96   4.96   4.96   4.96   4.96   4.
CALL  7   18:37
          TIM CALL
          TIM CALL
          TIM CALL
          DIAGNOST -192   4.96   4.96   4.96   4.96   4.96   4.96   4.96   4.
CALL  6   18:38
          TIM CALL
          TIM CALL
          TIM CALL
          DIAGNOST -192   4.96   4.96   4.96   4.96   4.96   4.96   4.96   4.
CALL  7   18:39
          TIM CALL
          TIM CALL
          TIM CALL
          DIAGNOST -192   4.96   4.96   4.96   4.96   4.96   4.96   4.96

MAINTENANCE STATISTICS    DATE: 11-23-1985   TIME:
TIME OUT    6(13) 7(53) 6(13) 7(53)
TIM-S OUT   6( 2) 7( 2) 6( 2) 7( 2)
LRC ERROR   6( 1) 7( 5) 6( 1)
OVERFLOW    6( 1) 7( 6) 6( 1)
PERM ERROR  6( 5) 7(22)
ORIG.CALLS  6(24)

*****
                                                                    4.96   4.96   4.

                                  4.96   4.96   4.96   4.96   4.96   4.96   4.9

          T    ST -192   4.96   4.96   4.96   4.96   4.96   4.96   4.96   4.9

MAINTENANCE STATISTICS    DATE: 11-23-1985   TIME: 18:41
TIME OUT    6(19) 7(59) 6(19) 7(59)
TIM-S OUT   6( 2) 7( 2) 6( 2) 7( 2)
LRC ERROR   6( 1) 7( 5) 6( 1) 7( 5)
OVERFLOW    6( 1) 7( 6) 6( 1) 7( 6)
PERM ERROR  6( 7) 7(24) 6( 7) 7(24)
ORIG.CALLS  6(26) 7(26) 6(26) 7(26)
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